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GEOTECHNICAL INVESTIGATION

CITY OF HOUSTON
BRAES UD WATER TANK REPLACEMENT
HOUSTON, TEXAS
WBS NO. S-000600-0038-3

Reported to

Brown and Gay Engineers, Inc.
Houston, Texas

by

Aviles Engineering Corporation
5790 Windfern
Houston, Texas 77041
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REPORT NO. G182-11

December 2011

AVILES ENGINEERING CORP.

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CITY OF HOUSTON
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1.0 INTRODUCTION

1.1 Project Description

This report presents the results of a geotechnical investigation performed by Aviles Engineering Corporation (AEC) for the proposed replacement of the City of Houston's (COH) Braes UD Nos. 1 and 2 Ground Storage Tanks (GST) located at 3710 Eldridge Parkway in Houston, Texas (Houston/Harris Key Map: 528B). A vicinity map is presented on Plate 1 in the Attachments. Based on the information provided, two existing 38.5 foot diameter by 24 foot high water storage tanks (GST Nos. 1 and 2) will be replaced by new tanks that have diameters and heights that are equal to the existing tanks.

1.2 Authorization

This investigation was authorized on October 10, 2011 by Mr. Douglas Baker, P.E., Project Manager of Brown and Gay Engineers, Inc., based upon AEC Proposal No. G2011-07-04R1, dated October 10, 2011.

1.3 Purpose and Scope

The purpose of this geotechnical investigation is to evaluate the subsurface soil and ground water conditions at the project site and to develop geotechnical engineering recommendations for design and construction of the GSTs. The scope of this geotechnical investigation is summarized below:

1. Drilling and sampling three soil borings varying in depth from 30 to 50 feet below existing grade;
2. Performing soil laboratory testing on selected soil samples;
3. Engineering analysis and recommendations for the GST foundations, allowable bearing capacity, and subgrade preparation;
4. Settlement analysis of the tank foundations; and
5. Construction recommendations for the tank foundations and tank pad preparations.

2.0 SUBSURFACE EXPLORATION

Based on the project schedule, the existing tanks were not removed prior to arrival of our drill rig. As a result, the borings are located outside the tank perimeters. Subsurface conditions were investigated by drilling three borings to depths ranging from 30 to 50 feet below existing grade adjacent to the existing GST perimeters. After completion of drilling, the boring locations were surveyed. Boring survey data is presented on the representative boring logs. The boring locations are shown on the attached Boring Location Plan on Plate 2, in the Attachments.

The borings were drilled using a truck-mounted drill rig. Borings were performed initially by dry auger method, then using wet rotary method once the borings caved in or saturated granular soils were encountered. Undisturbed samples of cohesive soils were obtained from the borings by pushing 3-inch diameter thin-wall, seamless steel Shelby tube samplers in accordance with ASTM D 1587. Granular soils were sampled with a 2-inch split-barrel sampler in accordance with ASTM D 1586. Standard Penetration Test resistance (N) values were recorded for the granular soils as "Blows per Foot" and are shown on the boring logs. Strength of the cohesive soils was estimated in the field using a hand penetrometer. The undisturbed samples of cohesive soils were extruded mechanically from the core barrels in the field and wrapped in aluminum foil; all samples were sealed in plastic bags to reduce moisture loss and disturbance. The samples were then placed in core boxes and transported to the AEC laboratory for testing and further study. The borings were backfilled with soil cuttings upon completion of drilling. Details of the soils encountered in the borings are presented on Plates 3 through 5, in the Attachments.

3.0 LABORATORY TESTING

Soil laboratory testing was performed by AEC personnel. Samples from the borings were examined and classified in the laboratory by a technician under supervision of a geotechnical engineer. Laboratory tests were performed on selected soil samples in order to evaluate the engineering properties of the foundation soils in accordance with applicable ASTM Standards. Atterberg limits, moisture contents, percent passing a No. 200 sieve, and dry unit weight tests were performed on representative samples to establish the index properties and confirm field classification of the subsurface soils. Strength properties of cohesive soils were estimated by means of unconfined compression (UC) tests and Unconsolidated-Undrained (UU) triaxial tests performed on undisturbed samples. The test results are presented on their representative boring logs. A key to the boring logs, classification of soils for engineering purposes, terms used on boring logs, and reference ASTM Standards for laboratory testing are presented on Plates 6 through 9, in the Attachments.

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A one-dimensional consolidation test was performed on a selected soil sample in order to evaluate the general compressibility characteristics of the clay soils in the site. The results of the consolidation test are presented on Plate 10, in the Attachments. The initial void ratio, compression index, recompession index, preconsolidation pressure, and estimated overconsolidation ratio (OCR) for the consolidation tests are summarized in Table 1.

Table 1. Summary of Consolidation Test Results

Sample ID and Description	e_0	C_c	C_r	p_c (tsf)	OCR
B-1, 6'-8', Sandy Lean Clay (CL)	0.5413	0.1506	0.0223	4.6	11.0

Note: (1) e_0 = initial void ratio;
(2) C_c = compression ratio;
(3) C_r = recompession ratio, which is derived from the recompession curve within the stress range from 2 to 8 ksf;
(4) p_c = preconsolidation pressure; and
(5) OCR = overconsolidation ratio.

4.0 SITE CONDITIONS

Based on our site visit on October 14, 2011, there are currently two GST's and an elevated storage tank at the facility, with a one story building located to the northwest of GST No. 1. The area around GST Nos. 1 and 2 is basically flat and covered in mowed grass.

4.1 Subsurface Conditions

Soil strata encountered in our borings are summarized below:

Boring	Depth	Description of Stratum
B-1	0' - 10'	Stiff to hard, Sandy Lean Clay (CL)
	10' - 26'	Medium dense to dense, Clayey Sand (SC)
	26' - 37'	Stiff to very stiff, Lean Clay w/Sand (CL)
	37' - 47'	Dense, Clayey Sand (SC)
	47' - 50'	Hard, Fat Clay (CH)
B-2	0' - 2'	Clayey Sand (SC)
	2' - 8'	Stiff to very stiff, Sandy Lean Clay (CL)
	8' - 12'	Medium dense, Clayey Sand (SC)
	12' - 18'	Loose to medium dense, Silty Sand (SM)
	18' - 30'	Dense to very dense, Poorly Graded Sand w/Silt (SP-SM)
B-3	0' - 8'	Very stiff to hard, Sandy Lean Clay (CL)
	8' - 18'	Medium dense, Clayey Sand (SC)
	18' - 30'	Medium dense to dense, Poorly Graded Sand w/Silt (SP-SM)

Details of the soils encountered during drilling are presented on the boring logs. The cohesive soils encountered in our borings have Liquid Limits (LL) ranging from 39 to 47 and Plasticity Indices (PI) ranging from 20 to 30. This indicates that the cohesive soils have moderate to high expansive potential. The cohesive soils encountered are classified as "CL" and "CH" type soils and the granular soils are classified as "SC", "SM", and "SP-SM" type soils in accordance with the Unified Soil Classification System (USCS). "CH" soils can undergo significant volume changes due to seasonal changes in moisture contents. "CL" soils with lower LL (less than 40) and PI (less than 20) generally do not undergo significant volume changes with changes in moisture content. However, "CL" soils with LL approaching 50 and PI greater than 20 essentially behave as "CH" soils and could undergo significant volume changes.

Although groundwater was not encountered during drilling, the borings caved in at 18 to 20 feet below grade. As a result, AEC has conservatively assumed that the ground water levels at the site are equal to the boring cave in depths. The information in this report summarizes conditions found on the date the borings were drilled. However, it should be noted that our ground water observations are short term; ground water depths and subsurface soil moisture contents will vary with environmental variations such as frequency and magnitude of rainfall and the time of year when construction is in progress.

4.2 Subsurface Variations

It should be emphasized that: (i) at any given time, ground water depths can vary from location to location, and (ii) at any given location, ground water depths can change with time. Ground water depths will vary with seasonal rainfall and other climatic/environmental events. Subsurface conditions may vary between borings.

Clay soils in the Houston area typically have secondary features such as slickensides and contain sand/silt seams/lenses/layers/pockets. It should be noted that the information in the boring logs is based on 3-inch diameter soil samples which were generally obtained at intervals of 2 feet in the top 20 feet of the borings and at intervals of 5 feet thereafter to the boring termination depths. A detailed description of the soil secondary features may not have been obtained due to the small sample size and sampling interval between the samples. Therefore, while some of AEC's logs show the soil secondary features, it should not be assumed that the features are absent where not indicated on the logs.

5.0 ENGINEERING ANALYSIS AND RECOMMENDATIONS

Based on the information provided, two existing 38.5 foot diameter by 24 foot high water storage tanks (GST Nos. 1 and 2) will be replaced by new tanks that have diameters and heights that are equal to the existing tanks.

5.1 Demolition of Existing Tank Foundation

After the foundation of the existing GSTs are removed, the exposed subgrade should be inspected by qualified geotechnical personnel to identify and remove any loose concrete, weak, compressible, or other unsuitable materials; such materials should be replaced with compacted select fill or clean stabilized soils. Subgrade preparation for the new tank foundations and pads are presented in Section 5.2.2 of this report.

5.2 New Ground Storage Tank

AEC understands that the existing tanks are supported on a ring wall type foundation and that the replacement tanks will also be supported on a similar ring wall type foundation. AEC anticipates that the Finished Floor Elevation (FFE) of the new tanks will be the same as the existing tank. Based on the information provided, the new GSTs will be located within the same footprint of the existing GSTs and will have a diameter and height equal or less than the existing GSTs. It should be noted that if the new tanks have a larger diameter, height, or is offset from the original tank locations, additional stresses from the new tanks will cause additional settlement/differential settlement to occur.

5.2.1 Tank Ring Wall Foundation

We understand that both of the ground storage tanks will be supported by ring wall foundations. To provide competent soil support for the tank foundations, we recommend that the ring wall foundations be extended to a minimum depth of 3 feet below existing grade. A ring wall foundation at a depth of 3 feet below existing grade should be designed for an allowable net bearing capacity of 2,000 psf for dead loads and 3,000 psf for total loads. A minimum safety factor of 3 and 2 was applied for sustained loads and total loads, respectively; whichever bearing capacity is critical should be used for design.

Since the foundation will be subjected to hoop stresses, adequate reinforcement will be required to resist these forces. For the calculation of the lateral pressure on the ring wall foundation, we recommend that at-rest earth pressure be considered. The coefficient of earth pressure at-rest, $K_0 = 0.95$, can be used in the design. At-rest pressure, p_h (psf), at a depth of Z ft below finished grade inside the ring wall can be calculated as:

$$P_h = (p_0 + \gamma Z)*K_0 \qquad \text{...........Equation (1)}$$

where, p_0 = tank pressure at the finished grade elevation, psf;
γ = wet unit weight of soil, 135 pcf;
Z = depth below finished grade, ft; and
K_0 = coefficient of earth pressure at-rest

Foundation Settlements: AEC understands that the new tank load will be equal to or less than the load of the existing GST. For our analysis, we have calculated settlements based on our boring logs, soil laboratory testing results, and anticipated tank load.

Using a net foundation pressure of 1,500 psf for the tank over a 38.5 foot diameter base, we estimated total settlement (which includes both immediate and long-term settlement, respectively) at the center and edge of both tanks. A summary of the tank settlements is presented on Table 2.

Table 2. Tank Settlements (Based on Borings B-1 through B-3)

Tank ID	Tank Height (ft)	δ_v (in)	S_{c1} (in)	S_{c2} (in)	Total S (in)
GST No. 1 (Center)	24	1.0	0.5	2.0	3.5
GST No.1 (Edge)	24	1.0	0.3	0.8	2.1
GST No. 2 (Center)	24	0.7	0.6	1.3	2.6
GST No. 2 (Edge)	24	0.7	0.4	0.8	1.9

Note: (1) δ_v = immediate settlement, S_{c1} = Estimated settlement resulting from granular soils; S_{c2} = Estimated consolidation settlement resulting from clayey soils; Total settlement, $S = \delta_v + S_{c1} + S_{c2}$.

AEC estimates a rebound heave of 0.2 inches, due to the excavation depth of the new ring wall foundation. Since the foundation soils under the existing tank are partially consolidated depending on the time the existing tank has been in place, AEC anticipates the settlement at the tank centers due to the new tank load will be less than 2.6 to 3.5 inches (based on Table 2).

Time Rate of Consolidation Settlement: Time rates of foundation settlements are plotted as curves of percent total consolidation settlement versus time for the abutments and embankments on Plate 11, in the Attachments. The curve is based on the assumption of a one-month linear construction period, i.e. the foundation soils will be loaded linearly during construction.

Frequently, the predicted settlement time is longer than that observed in the field for the following reasons: (1) theoretical conditions assumed for the consolidation analysis do not hold in-situ because of intermediate lateral drainage, anisotropy in permeability, time dependency of real loading, and the variation of soil properties with effective stress; and (2) the coefficient of consolidation, as determined in the laboratory, decreases with sample disturbance; therefore, predicted settlement time tends to be greater than actual settlement time.

5.2.2 Tank Pad Preparation

Subgrade preparation should extend a minimum of 5 feet beyond the tank perimeter. AEC recommends that the top 12 inches of existing soil at the ground surface be excavated and wasted; the excavation depth should be increased wherever non-granular soils are encountered (such as the area around Boring B-2), or soils disturbed by demolition of the existing tank foundation (see Section 5.1 of this report). The exposed bottom should be proof-rolled in accordance with Item 216 of the 2004 TXDOT Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges. Soft areas revealed by proof-rolling should be over-excavated and replaced with compacted select fill. After proof rolling, compacted select fill shall be used to achieve the design grade. Compacted select fill requirements are presented in Section 5.3 of this report. We recommend that the final subgrade surface be crowned about 2 inches higher at the tank center than the edge, since the settlement at the tank center is typically higher than the tank edge.

5.3 Select Fill

Select fill should consist of uniform, non-active inorganic lean clays with a PI between 10 and 20 percent, and more than 50 percent passing a No. 200 sieve. Excavated material delivered to the site for use as select fill shall not have clay clods with PI greater than 20, clay clods greater than 2 inches in diameter, or contain sands/silts with PI less than 10. Prior to construction, the Contractor should determine if he or she can obtain qualified select fill meeting the above select fill criteria.

As an alternative to imported fill, on-site soils excavated during construction can be stabilized with a minimum of 6 percent hydrated lime (by dry soil weight), as determined by lime-series curve or pH method in a laboratory prior to construction. Lime stabilization should be done in general accordance with the latest City of Houston Standard Construction Specifications (COHSCS). AEC prefers using stabilized on-site clay as select fill since compacted lime-stabilized clay generally has high shear strength, low compressibility, and relatively low permeability. Blended or mixed soils (sand and clay) should not be used as select fill.

All imported material intended for use as select fill should be tested prior to use to confirm that it meets select fill criteria. Select fill should be placed in loose lifts not exceeding 8 inches in thickness. Backfill within 3 feet of walls or columns should be placed in loose lifts no more than 4-inches thick and compacted using hand tampers, or small self-propelled compactors. The select fill should be compacted to a minimum of 95 percent of the ASTM D 698 (Standard Proctor) maximum dry unit weight at a moisture content ranging between optimum and 3 percent above optimum.

At least one Atterberg Limits and one percent passing a No. 200 sieve test shall be performed for each 5,000 square feet (sf) of placed fill, per lift (with a minimum of one set of tests per lift), to determine whether it meets select fill requirements. Prior to placement of concrete, the moisture contents of the top 2 lifts of compacted select fill shall be re-tested (if there is an extended period of time between fill placement and pavement construction) to determine if the in-place moisture content of the lifts have been maintained at the required moisture requirements.

6.0 CONSTRUCTION CONSIDERATIONS

6.1 Site Preparation and Grading

To mitigate site problems that may develop following prolonged periods of rainfall, it is essential to have adequate drainage to maintain a relatively dry and firm surface prior to starting any work at the site. Adequate drainage should be maintained throughout the construction period. Methods for controlling surface runoff and ponding include proper site grading, berm construction around exposed areas, and installation of sump pits with pumps.

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6.2 Construction Monitoring

Site preparation (including clearing and proof-rolling), earthwork operations, foundation construction, and subgrade preparation should be monitored by qualified geotechnical professionals to check for compliance with project documents and changed conditions, if encountered.

7.0 GENERAL

AEC should be allowed to review construction documents and specifications prior to release to check that the geotechnical recommendations and design criteria presented herein are properly interpreted.

The information contained in this report summarizes conditions found on the date the borings were drilled. The attached boring logs are true representations of the soils encountered at the specific boring locations on the date of drilling. Due to variations encountered in the subsurface conditions across the site, changes in soil conditions from those presented in this report should be anticipated. AEC should be notified immediately when conditions encountered during construction are significantly different from those presented in this report.

8.0 LIMITATIONS

The investigation was performed using the standard level of care and diligence normally practiced by recognized geotechnical engineering firms in this area, presently performing similar services under similar circumstances. The report has been prepared exclusively for the project and location described in this report, and is intended to be used in its entirety. If pertinent project details change or otherwise differ from those described herein, AEC should be notified immediately and retained to evaluate the effect of the changes on the recommendations presented in this report, and revise the recommendations if necessary. The scope of services does not include a fault investigation. The recommendations presented in this report should not be used for other structures located at this site or similar structures located at other sites, without additional evaluation and/or investigation.

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9.0 CLOSING REMARKS

AEC appreciates the opportunity to be of service on this project and looks forward to our continuing association during the construction phase of this project and on future projects.

AVILES ENGINEERING CORPORATION
(TBPE Firm Registration No. F-42)

12/7/11

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Principal Engineer

December 7, 2011

Reports Submitted:	3	Brown and Gay Engineers, Inc.
	1	File

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ATTACHMENTS

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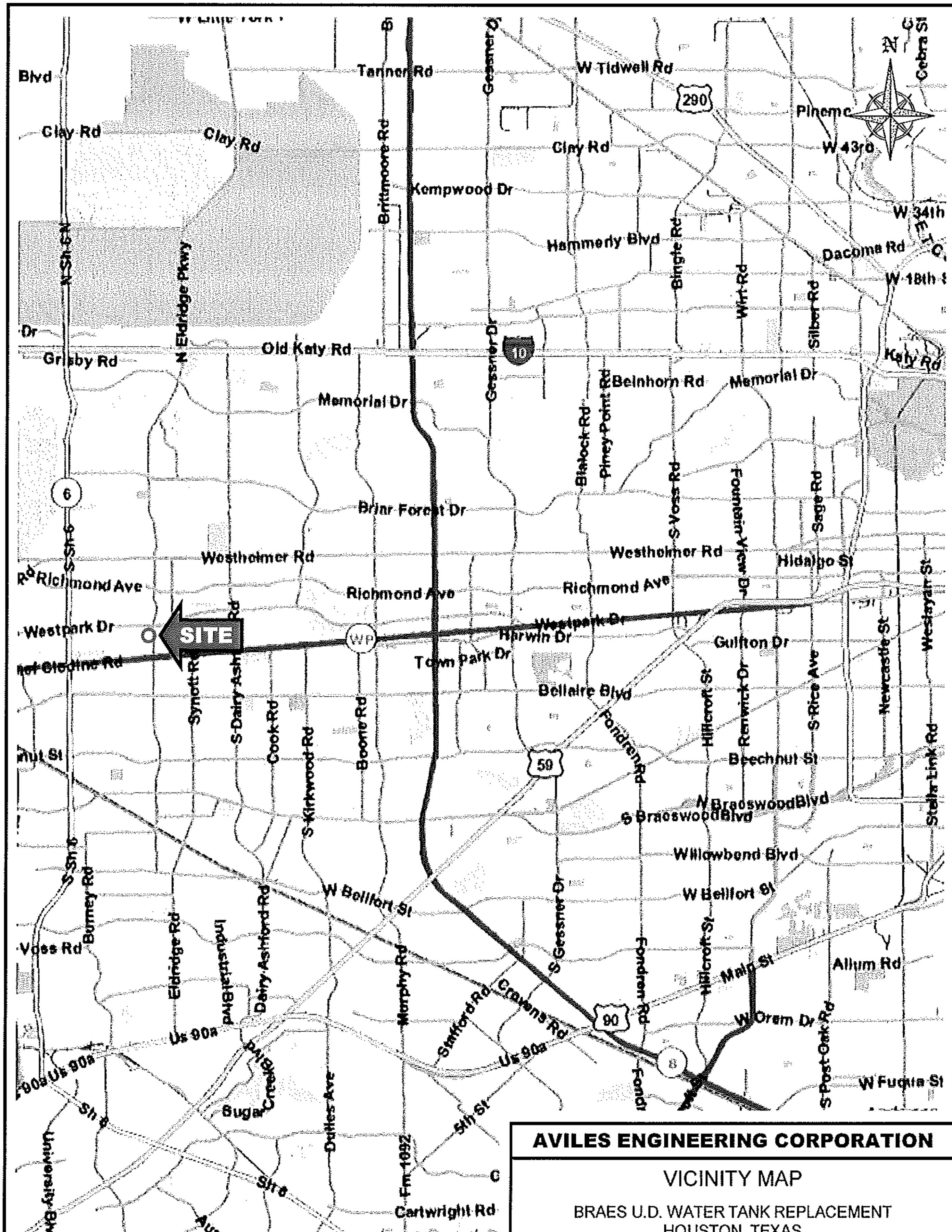
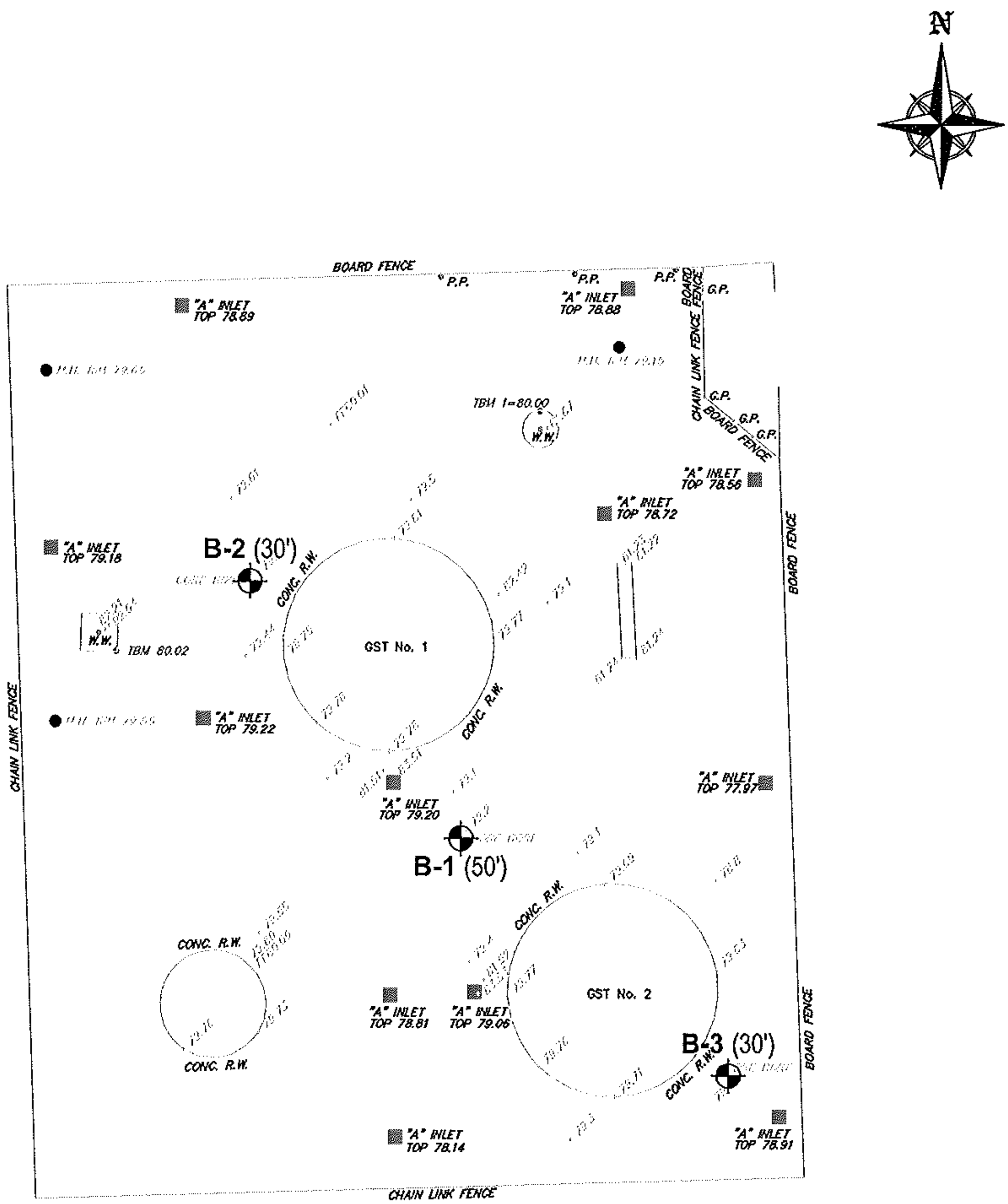


AVILES ENGINEERING CORPORATION		
VICINITY MAP BRAES U.D. WATER TANK REPLACEMENT HOUSTON, TEXAS		
AEC PROJECT NO: G182-11	DATE: 11-29-11	SOURCE DRAWING PROVIDED BY: C.O.H. GIMS
APPROX. SCALE: N.T.S.	DRAFTED BY: BpJ	PLATE NO: PLATE 1



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BORING LOCATION PLAN

BRAES U.D. WATER TANK REPLACEMENT
HOUSTON, TEXAS

AEC PROJECT NO.: G182-11	DATE: 12-05-11	SOURCE DRAWING PROVIDED BY: BROWN & GAY ENG.
SCALE: 1" = 30'	DRAFTED BY: BpJ	PLATE NO.: PLATE 2

PROJECT: **COH Braes UD Water Tank Replacement**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

BORING **B-1**

DATE **10/14/11** TYPE **4" Dry Auger / Wet Rotary** LOCATION **See Boring Location Plan**

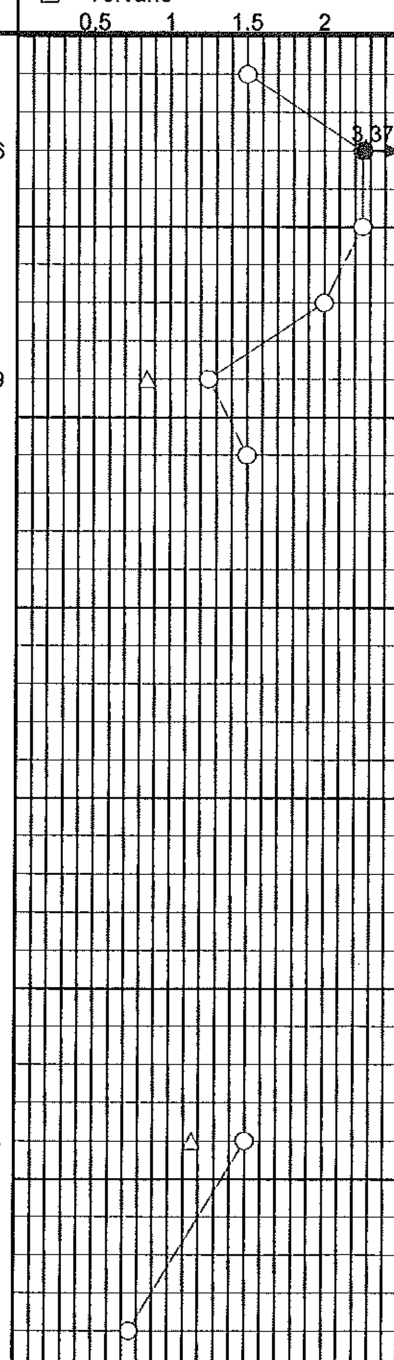
DESCRIPTION

Texas State Plane Coordinates (feet):
Easting: 3039785.96
Northing: 13823934.00
Elevation: 79.46

DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0	Stiff to hard, dark brown Sandy Lean Clay (CL)		18		59	40	16	24
	-tan 2'-6', with calcareous nodules2'-4'		15	116				
5			17					
	-olive-gray and tan 6'-10'		21		59	44	17	27
			17	109				
10	Medium dense to dense, brown Clayey Sand (SC)		7					
		14	13					
15	-tan 14'-18'	26	15		37			
		31	19					
	-borehole caved in at 18' -reddish brown 18'-25'	12	27					
20								
		31	23					
25								
	Stiff to very stiff, reddish tan Lean Clay w/ Sand (CL)							
			22	105				
30								
35			22		84	34	15	19

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **18** FEET WHILE DRILLING
WATER LEVEL AT **N/A** FEET AFTER **N/A**
DRILLED BY **V&S** CHECKED BY **WLW** LOGGED BY **V&S**

PROJECT NO. G182-11

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

PROJECT: COH Braes UD Water Tank Replacement BORING B-1

DATE 10/14/11 TYPE 4" Dry Auger / Wet Rotary LOCATION See Boring Location Plan

DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	SHEAR STRENGTH, TSF (△ Confined Compression; ● Unconfined Compression; ○ Pocket Penetrometer; □ Torvane; scale 0.5, 1, 1.5, 2)	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
			Lean Clay w/Sand... (continued)								
			Dense, tan Clayey Sand (SC)								
40				36	21						
45				45	17						
			Hard, reddish brown Fat Clay (CH)		22						
50			Termination depth = 50 feet.								
55											
60											
65											
70											

BORING DRILLED TO 18 FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT 18 FEET WHILE DRILLING ▽
WATER LEVEL AT N/A FEET AFTER N/A ▼
DRILLED BY V&S CHECKED BY WLW LOGGED BY V&S

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PROJECT: COH Braes UD Water Tank Replacement

BORING B-2

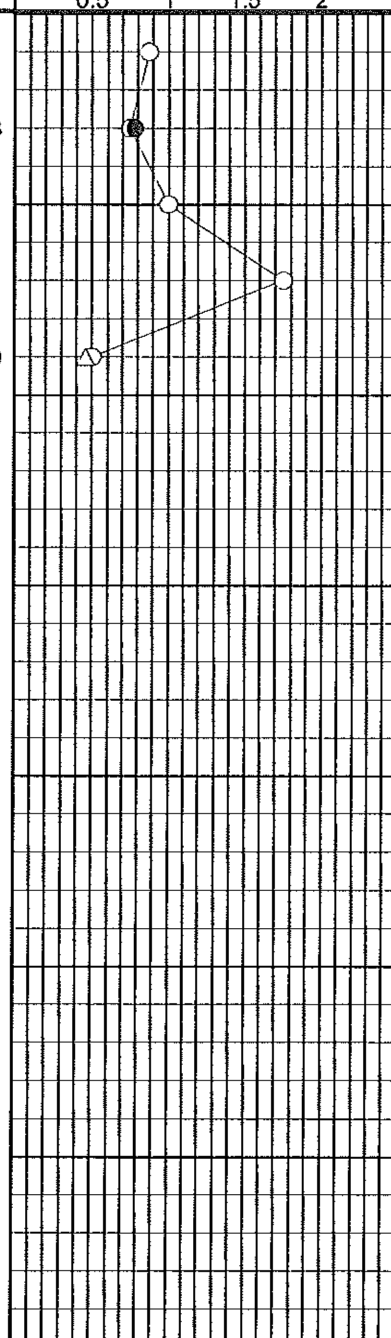
DATE 10/14/11 TYPE 4" Dry Auger / Wet Rotary LOCATION See Boring Location Plan

DESCRIPTION

Texas State Plane Coordinates (feet):
Easting: 3039746.53
Northing: 13823981.43
Elevation: 79.59

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0	Dark brown Clayey Sand (SC)		13		33	39	19	20
	Stiff to very stiff, dark brown Sandy Lean Clay (CL)		25	103				
5	-light gray 4'-6'		22					
	-tan and olive-gray, with calcareous nodules 6'-8'		18		55	44	17	27
	Medium dense, reddish brown Clayey Sand (SC)		22	110				
10	-tan and brown 10'-12'	15	23					
	Loose to medium dense, tan and brown Silty Sand (SM)	7	9		30			
15		16	10					
		21	18					
	Dense to very dense, brown and tan Poorly Graded Sand w/Silt (SP-SM)	50/2"	20		11			
20	-borehole caved in at 20'							
25		31	20					
		49	22					
30	Termination depth = 30 feet.							
35								

BORING DRILLED TO 20 FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT 20 FEET WHILE DRILLING
WATER LEVEL AT N/A FEET AFTER N/A
DRILLED BY V&S CHECKED BY WLW LOGGED BY V&S

PROJECT NO. G182-11

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

PROJECT: **COH Braes UD Water Tank Replacement** BORING **B-3**

DATE **10/14/11** TYPE **4" Dry Auger / Wet Rotary** LOCATION **See Boring Location Plan**

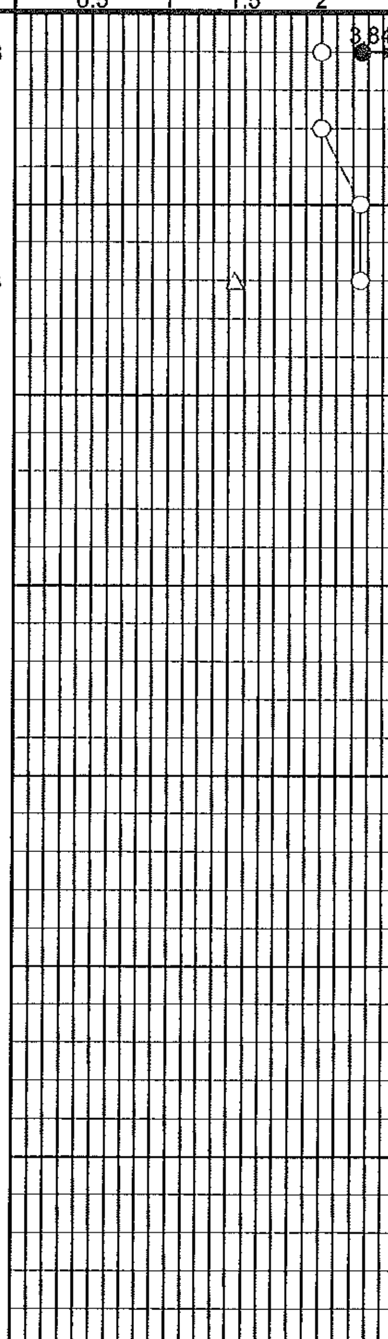
DESCRIPTION

Texas State Plane Coordinates (feet):
Easting: 3039836.06
Northing: 13823890.20
Elevation: 78.93

SHEAR STRENGTH, TSF: △ Confined Compression; ● Unconfined Compression; ○ Pocket Penetrometer; □ Torvane (scale 0.5, 1, 1.5, 2)

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35

Description	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
Very stiff to hard, dark brown Sandy Lean Clay (CL), with calcareous nodules		15	108				
-olive-gray and tan 2'-4'		18					
-tan and brown 4'-8'		14		50	47	17	30
		14	113				
Medium dense, tan Clayey Sand (SC)	13	7					
	16	6					
	21	9					
	22	5		28			
	19	4					
Medium dense to dense, tan Poorly Graded Sand w/Silt (SP-SM), wet -borehole caved in at 20'	14	6		8			
	50	18					
	44	19					
Termination depth = 30 feet.							



BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **20** FEET WHILE DRILLING
WATER LEVEL AT **N/A** FEET AFTER **N/A**
DRILLED BY **V&S** CHECKED BY **WLW** LOGGED BY **V&S**

KEY TO SYMBOLS

Symbol Description

<u>Strata symbols</u>

Low plasticity clay

Clayey sand

High plasticity clay

Silty sand

Poorly graded sand with silt

<u>Misc. Symbols</u>

∇ Water table depth during drilling

○ Pocket Penetrometer

● Unconfined Compression

△ Confined Compression

<u>Soil Samplers</u>

Undisturbed thin wall Shelby tube

Standard penetration test

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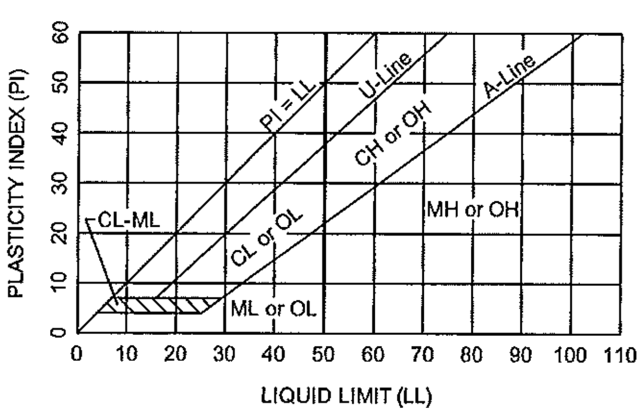
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation D-2487

MAJOR DIVISIONS				GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (Less than 50% of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well-graded gravel, well-graded gravel with sand
				GP	Poorly-graded gravel, poorly-graded gravel with sand
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	GM	Silty gravel, silty gravel with sand
			Limits plot above "A" line & hatched zone on plasticity chart	GC	Clayey gravel, clayey gravel with sand
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well-graded sand, well-graded sand with gravel
				SP	Poorly-graded sand, poorly-graded sand with gravel
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	SM	Silty sand, silty sand with gravel
			Limits plot above "A" line & hatched zone on plasticity chart	SC	Clayey sand, clayey sand with gravel
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)		SILTS AND CLAYS (Liquid Limit Less Than 50%)		ML	Silt, silt with sand, silt with gravel, sandy silt, gravelly silt
				CL	Lean clay, lean clay with sand, lean clay with gravel, sandy lean clay, gravelly lean clay
				OL	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt
		SILTS AND CLAYS (Liquid Limit 50% or More)		MH	Elastic silt, elastic silt with sand, sandy elastic silt, gravelly elastic silt
				CH	Fat clay, fat clay with sand, fat clay with gravel, sandy fat clay, gravelly fat clay
				OH	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt

NOTE: Coarse soils between 5% and 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone of the plasticity chart are to have dual symbols.

PLASTICITY CHART



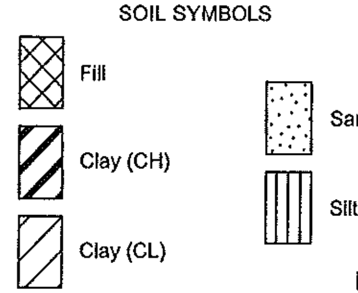
Equation of A-Line: Horizontal at PI=4 to LL=25.5, then PI=0.73(LL-20)

Equation of U-Line: Vertical at LL=16 to PI=7, then PI=0.9(LL-8)

DEGREE OF PLASTICITY OF COHESIVE SOILS

Degree of Plasticity	Plasticity Index
None	0 - 4
Slight	5 - 10
Medium	11 - 20
High	21 - 40
Very High	>40

SOIL SYMBOLS



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TERMS USED ON BORING LOGS

SOIL GRAIN SIZE

U.S. STANDARD SIEVE

6"	3"	3/4"	#4	#10	#40	#200		
BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE		
152	76.2	19.1	4.76	2.00	0.420	0.074	0.002	

SOIL GRAIN SIZE IN MILLIMETERS

STRENGTH OF COHESIVE SOILS

Consistency	Undrained Shear Strength, Kips per Sq. ft.
Very Soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	greater than 4.00

RELATIVE DENSITY OF COHESIONLESS SOILS FROM STANDARD PENETRATION TEST

Very Loose	<4 bpf
Loose	5-10 bpf
Medium Dense	11-30 bpf
Dense	31-50 bpf
Very Dense	>50 bpf

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows per Foot	Description
25	25 blows driving sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows driving sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows driving sampler 3 inches, during initial 6-inches seating interval.

NOTE: To avoid change to sampling tools, driving is limited to 50 blows during or after seating interval.

DRY STRENGTH ASTM D2488

None	Dry specimen crumbles into powder with mere pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable pressure
High	Dry specimen cannot be broken with finger pressure, it can be broken between thumb and hard surface
Very High	Dry specimen cannot be broken between thumb and hard surface

MOISTURE CONDITION ASTM D2488

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

SOIL STRUCTURE

Slickensided	Having planes of weakness that appear slick and glossy. The degree of slickensidedness depends upon the spacing of slickensides and the easiness of breaking along these planes.
Fissured	Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	Inclusion less than 1/8 inch thick extending through the sample.
Seam	Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer	Inclusion greater than 3 inches thick extending through the sample.
Laminated	Soil sample composed of alternating partings or seams of different soil types.
Interlayered	Soil sample composed of alternating layers of different soil types.
Intermixed	Soil sample composed of pockets of different soil types and layered or laminated structure is not evident.
Calcareous	Having appreciable quantities of calcium material.

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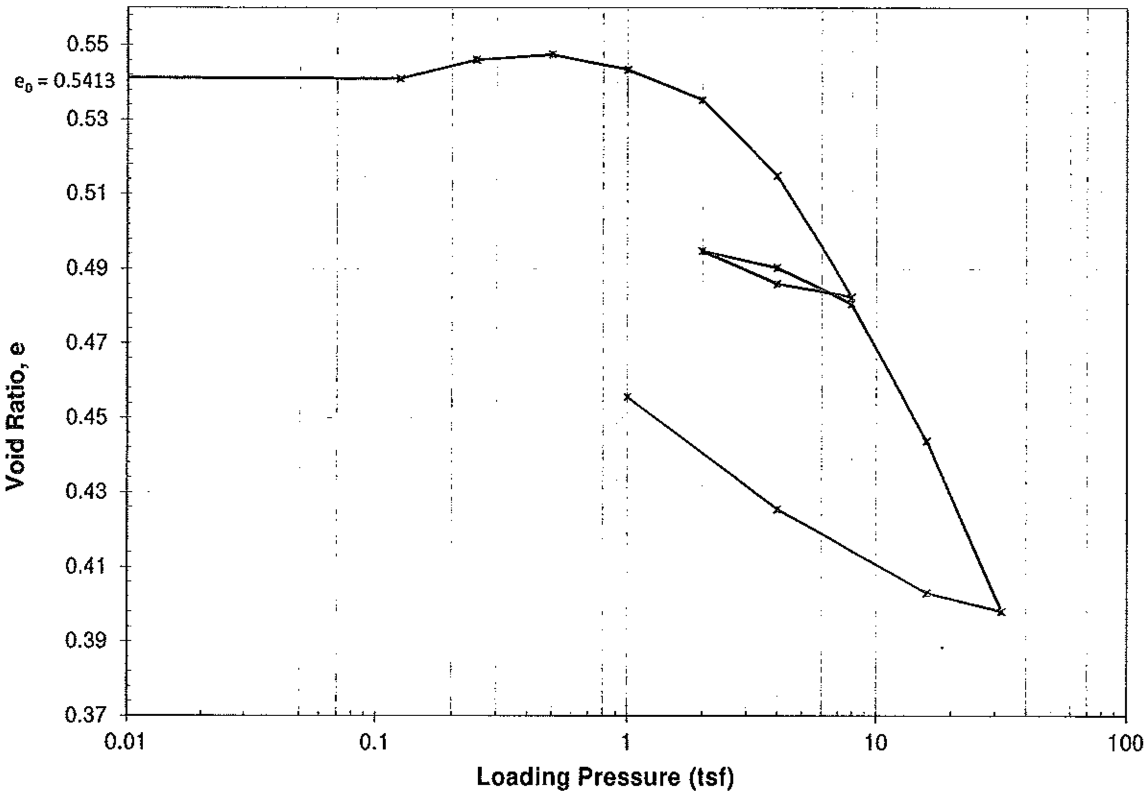
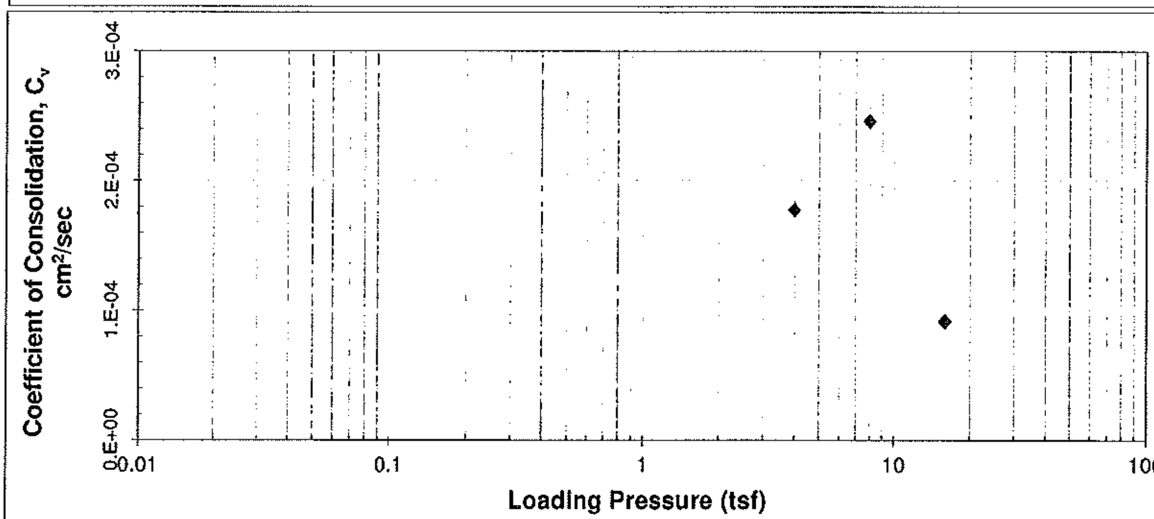
ASTM & TXDOT DESIGNATION FOR SOIL LABORATORY TESTS

NAME OF TEST	ASTM TEST DESIGNATION	TXDOT TEST DESIGNATION
Moisture Content	D 2216	Tex-103-E
Specific Gravity	D 854	Tex-108-E
Sieve Analysis	D 421 D 422	Tex-110-E (Part 1)
Hydrometer Analysis	D 422	Tex-110-E (Part 2)
Minus No. 200 Sieve	D 1140	Tex-111-E
Liquid Limit	D 4318	Tex-104-E
Plastic Limit	D 4318	Tex-105-E
Shrinkage Limit	D 427	Tex-107-E
Standard Proctor Compaction	D 698	Tex-114-E
Modified Proctor Compaction	D 1557	Tex-113-E
Permeability (constant head)	D 2434	-
Consolidation	D 2435	-
Direct Shear	D 3080	-
Unconfined Compression	D 2166	-
Unconsolidated-Undrained Triaxial	D 2850	Tex-118-E
Consolidated-Undrained Triaxial	D 4767	Tex-131-E
Pinhole Test	D 4647	-
California Bearing Ratio	D 1883	-
Unified Soil Classification System	D 2487	Tex-142-E

CONSOLIDATION TEST RESULTS



Project No.: G182-11 Project: COH Braes UD Water Tank Replacement
Sample ID: B-1, 6 ft to 8 ft
Sample Description: Gray and tan Sandy Lean Clay (CL) Dry Unit Weight (γ_d): 113 pcf
Estimated Consolidation Index (Cc): 0.1506 Estimated Recompression Index (Cr): 0.0223
Estimated OCR: 11.0 Estimated Preconsolidation Pressure (Pc): 4.6 tsf



ESTIMATED TIME RATE OF CONSOLIDATION SETTLEMENT IN CLAYS

(Assuming one-month Construction Period Starting at Time 0)

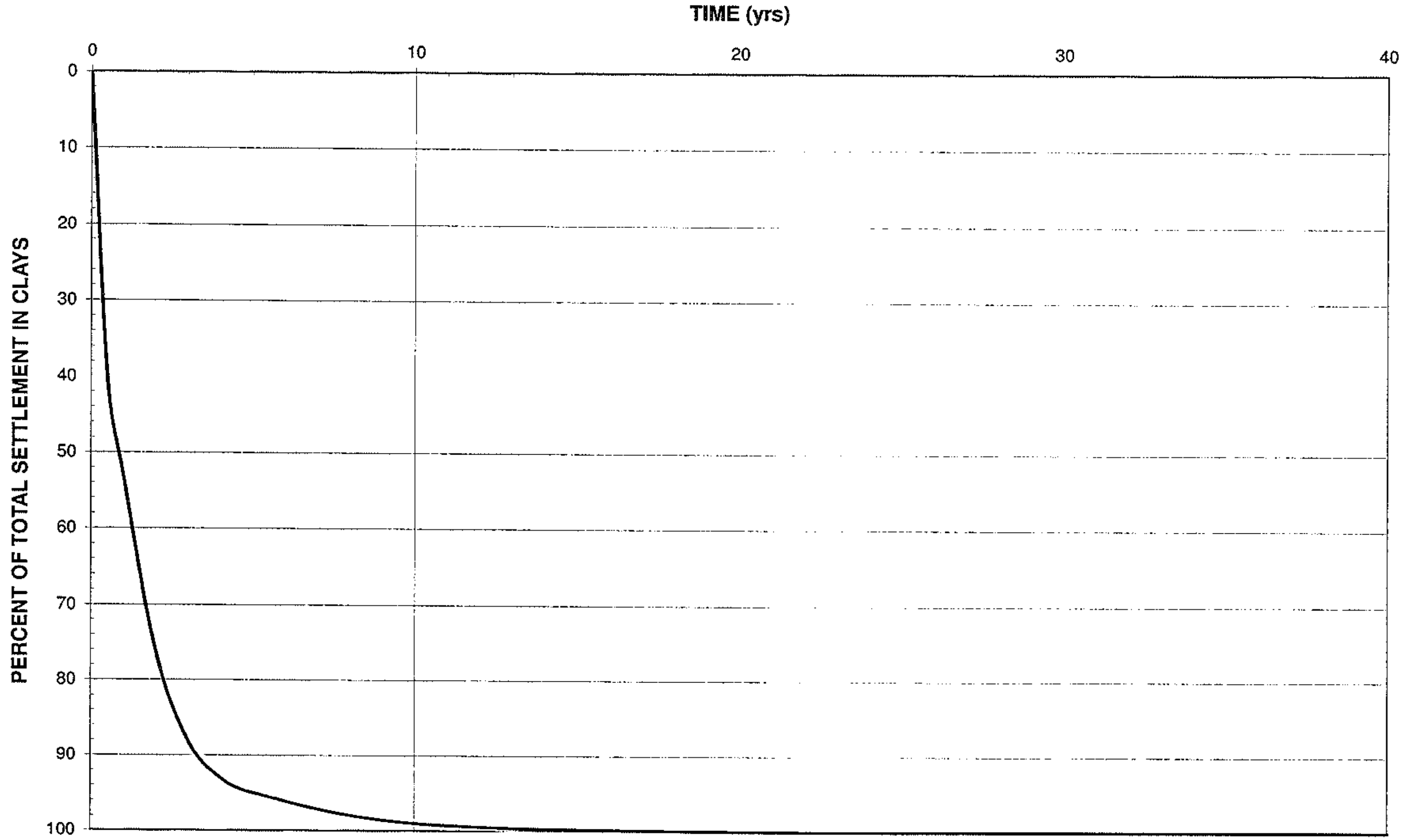


PLATE 11